

IN THE CLAIMS:

Claims 1-4, 6-19, 21-34, 36-49, and 51-60 are re-presented.

1. (Previously presented) A method of operating a storage system, comprising:
 - storing a plurality of data blocks having a horizontal redundant relationship;
 - storing a plurality of checksums, each checksum having a vertical redundant relationship with a corresponding one of the plurality of data blocks;
 - in response to an indication of a data integrity error in at least one of the plurality of data blocks, determining whether the vertical redundant relationship between each of the remaining data blocks and the corresponding checksums indicates an error; and
 - determining whether the horizontal redundant relationship between the plurality of data blocks indicates an error.
2. (Previously presented) The method of Claim 1, wherein:
 - said determining whether the vertical redundant relationship between each of the remaining data blocks and the corresponding checksums indicates an error comprises calculating a new checksum for each of the remaining data blocks in the plurality of data blocks and comparing the calculated new checksum to the checksum from the plurality of checksums corresponding to that data block.
3. (Original) The method of Claim 1, wherein:
 - said storing the plurality of checksums comprises storing the plurality of checksums such that each data block in the plurality of data blocks has a vertical redundant relationship with a set of corresponding checksums, and each of the checksums in the set of corresponding checksums has a horizontal checksum redundant relationship with the other checksums in the set of corresponding checksums.

4. (Original) The method of Claim 3, further comprising:

in response to detecting a first data integrity error between a first data block and a first checksum from a first set of checksums corresponding to the first data block, reviewing the vertical redundant relationship between the first data block and the remaining checksums in the first set of checksums; and
in response to detecting no data integrity errors between the first data block and the remaining checksums in the first set of checksums, creating a restored first checksum to replace the first checksum corresponding to the first data integrity error.

5. (Cancelled)

6. (Previously presented) The method of Claim 1, wherein:

said plurality of data blocks comprises a plurality of data stripe units and a parity stripe unit; and
said determining whether the horizontal redundant relationship between the plurality of data blocks indicates an error comprises calculating a new parity stripe unit based on the plurality of data stripe units and comparing the calculated new parity stripe unit to the parity stripe unit from the plurality of data blocks.

7. (Previously presented) The method of Claim 1, wherein:

said plurality of data blocks comprises a first mirrored data block and a corresponding second mirrored data block; and
said determining whether the horizontal redundant relationship between the plurality of data blocks indicates an error comprises comparing the first mirrored data block and the second mirrored data block.

8. (Previously presented) The method of Claim 1, further comprising:

in response to detecting a first data integrity error in exactly one of the vertical redundant relationships and detecting no data integrity errors in the horizontal redundant relationship, creating a restored checksum using the data block corresponding to the first data integrity error to replace the existing checksum corresponding to the first data integrity error.

9. (Previously presented) The method of Claim 1, further comprising:

in response to detecting a first data integrity error in exactly one of the vertical redundant relationships and detecting a second data integrity error in the horizontal redundant relationship, creating a restored data block using the horizontal redundant relationship to replace the data block corresponding to the first data integrity error and comparing the restored data block to the checksum corresponding to the first data integrity error.

10. (Original) The method of Claim 9, further comprising:

in response to a mismatch between the restored data block and the checksum corresponding to the first data integrity error, creating a restored checksum using the restored data block to replace the checksum corresponding to the first data integrity error.

11. (Previously presented) The method of Claim 1, further comprising:

in response to detecting a first data integrity error in a first vertical redundant relationship, detecting a second data integrity error in a second vertical redundant relationship, and detecting no data integrity errors in the horizontal redundant relationship, reporting a data loss condition.

12. (Previously presented) The method of Claim 1, further comprising:

in response to detecting a first data integrity error in a first vertical redundant relationship, detecting a second data integrity error in a second vertical

redundant relationship, and detecting a third data integrity error in the horizontal redundant relationship:

creating a first restored data block using the horizontal redundant relationship to replace the data block corresponding to the first vertical redundant relationship;

comparing the first restored data block to the checksum corresponding to the first vertical redundant relationship;

creating a second restored data block using the horizontal redundant relationship to replace the data block corresponding to the second vertical redundant relationship; and

comparing the second restored data block to the checksum corresponding to the second vertical redundant relationship.

13. (Original) The method of Claim 12, further comprising:

reporting a data loss condition in response to either:

- (a) a mismatch between the first restored data block and the checksum corresponding to the first vertical redundant relationship and a mismatch between the second restored data block and the checksum corresponding to the second vertical redundant relationship; or
- (b) a match between the first restored data block and the checksum corresponding to the first vertical redundant relationship and a match between the second restored data block and the checksum corresponding to the second vertical redundant relationship.

14. (Original) The method of Claim 12, further comprising:

in response to a match between the first restored data block and the checksum corresponding to the first vertical redundant relationship and a mismatch between the second restored data block and the checksum corresponding to the second vertical redundant relationship, creating a restored checksum using the second

restored data block to replace the checksum corresponding to the second vertical redundant relationship.

15. (Original) The method of Claim 1, further comprising:

in response to detecting data integrity errors in at least three of the vertical redundant relationships, reporting a data loss.

16. (Previously presented) A storage system, comprising:

a storage array comprising a plurality of storage devices;

a plurality of data blocks having a horizontal redundant relationship, each data block stored on one of the plurality of storage devices;

a plurality of checksums, each checksum having a vertical redundant relationship with a corresponding one of the plurality of data blocks; and

an array manager coupled to the storage array, wherein said array manager is configured such that in response to an indication of a data integrity error in at least one of the plurality of data blocks, said array manager determines whether the vertical redundant relationship between each of the remaining data blocks and the corresponding checksums indicates an error;

wherein the array manager further determines whether the horizontal redundant relationship between the plurality of data blocks indicates an error.

17. (Previously presented) The storage system of Claim 16, wherein:

said array manager is configured to determine whether the vertical redundant relationship between each of the remaining data blocks and the corresponding checksums indicates an error by calculating a new checksum for each of the remaining data blocks in the plurality of data blocks and comparing the calculated new checksum to the checksum from the plurality of checksums corresponding to that data block.

18. (Original) The storage system of Claim 16, wherein:

each data block in the plurality of data blocks has a vertical redundant relationship with a set of corresponding checksums, and each of the checksums in the set of corresponding checksums has a horizontal checksum redundant relationship with the other checksums in the set of corresponding checksums.

19. (Original) The storage system of Claim 18, wherein:

said array manager is configured such that in response to detecting a first data integrity error between a first data block and a first checksum from a first set of checksums corresponding to the first data block, said array manager reviews the vertical redundant relationship between the first data block and the remaining checksums in the first set of checksums; and

said array manager is further configured such that in response to detecting no data integrity errors between the first data block and the remaining checksums in the first set of checksums, said array manager creates a restored first checksum to replace the first checksum corresponding to the first data integrity error.

20. (Cancelled)

21. (Previously presented) The storage system of Claim 16, wherein:

said plurality of data blocks comprises a plurality of data stripe units and a parity stripe unit; and

said array manager is configured to determine whether the horizontal redundant relationship between the plurality of data blocks indicates an error by calculating a new parity stripe unit based on the plurality of data stripe units and comparing the calculated new parity stripe unit to the parity stripe unit from the plurality of data blocks.

22. (Previously presented) The storage system of Claim 16, wherein:

said plurality of data blocks comprises a first mirrored data block and a corresponding second mirrored data block; and

said array manager is configured to determine whether the horizontal redundant relationship between the plurality of data blocks indicates an error by comparing the first mirrored data block and the second mirrored data block.

23. (Previously presented) The storage system of Claim 16, wherein:

said array manager is configured such that in response to detecting a first data integrity error in exactly one of the vertical redundant relationships and detecting no data integrity errors in the horizontal redundant relationship, said array manager creates a restored checksum using the data block corresponding to the first data integrity error to replace the existing checksum corresponding to the first data integrity error.

24. (Previously presented) The storage system of Claim 16, wherein:

said array manager is configured such that in response to detecting a first data integrity error in exactly one of the vertical redundant relationships and detecting a second data integrity error in the horizontal redundant relationship, said array manager creates a restored data block using the horizontal redundant relationship to replace the data block corresponding to the first data integrity error and compares the restored data block to the checksum corresponding to the first data integrity error.

25. (Original) The storage system of Claim 24, wherein:

said array manager is configured such that in response to a mismatch between the restored data block and the checksum corresponding to the first data integrity error, said array manager creates a restored checksum using the restored data block to replace the checksum corresponding to the first data integrity error.

26. (Previously presented) The storage system of Claim 16, further comprising:

said array manager is configured such that in response to detecting a first data integrity error in a first vertical redundant relationship, detecting a second data integrity error in a second vertical redundant relationship, and detecting no data integrity errors in the horizontal redundant relationship, said array manager reports a data loss condition.

27. (Previously presented) The storage system of Claim 16, wherein:

said array manager is configured such that in response to detecting a first data integrity error in a first vertical redundant relationship, detecting a second data integrity error in a second vertical redundant relationship, and detecting a third data integrity error in the horizontal redundant relationship, said array manager:

- creates a first restored data block using the horizontal redundant relationship to replace the data block corresponding to the first vertical redundant relationship;
- compares the first restored data block to the checksum corresponding to the first vertical redundant relationship;
- creates a second restored data block using the horizontal redundant relationship to replace the data block corresponding to the second vertical redundant relationship; and
- compares the second restored data block to the checksum corresponding to the second vertical redundant relationship.

28. (Original) The storage system of Claim 27, wherein:

said array manager is configured such that said array manager reports a data loss condition in response to either:

- (a) a mismatch between the first restored data block and the checksum corresponding to the first vertical redundant relationship and a mismatch

between the second restored data block and the checksum corresponding to the second vertical redundant relationship; or

- (b) a match between the first restored data block and the checksum corresponding to the first vertical redundant relationship and a match between the second restored data block and the checksum corresponding to the second vertical redundant relationship.

29. (Original) The storage system of Claim 27, wherein:

said array manager is configured such that in response to a match between the first restored data block and the checksum corresponding to the first vertical redundant relationship and a mismatch between the second restored data block and the checksum corresponding to the second vertical redundant relationship, said array manager creates a restored checksum using the second restored data block to replace the checksum corresponding to the second vertical redundant relationship.

30. (Original) The storage system of Claim 16, wherein:

said array manager is configured to report a data loss condition in response to detecting data integrity errors in at least three of the vertical redundant relationships.

31. (Previously presented) A computer-readable medium whose contents cause a computer system to operate a storage system by performing the steps of:

detecting an indication of a data integrity error in at least one of a plurality of data block having a horizontal redundant relationship;
analyzing a plurality of checksums, each checksum having a vertical redundant relationship with a corresponding one of the plurality of data blocks, said analyzing comprising determining whether the vertical redundant relationship between each of the remaining data blocks and the corresponding checksums indicates an error; and
determining whether the horizontal redundant relationship between the plurality of

data blocks indicates an error.

32. (Previously presented) The computer-readable medium of Claim 31, wherein:

said determining whether the vertical redundant relationship between each of the remaining data blocks and the corresponding checksums indicates an error comprises calculating a new checksum for each of the remaining data blocks in the plurality of data blocks and comparing the calculated new checksum to the checksum from the plurality of checksums corresponding to that data block.

33. (Original) The computer-readable medium of Claim 31, wherein:

each data block in the plurality of data blocks has a vertical redundant relationship with a set of corresponding checksums, and each of the checksums in the set of corresponding checksums has a horizontal checksum redundant relationship with the other checksums in the set of corresponding checksums.

34. (Original) The computer-readable medium of Claim 33, wherein the contents of the computer-readable medium cause the computer system to operate the storage system by performing the further steps of:

in response to detecting a first data integrity error between a first data block and a first checksum from a first set of checksums corresponding to the first data block, reviewing the vertical redundant relationship between the first data block and the remaining checksums in the first set of checksums; and

in response to detecting no data integrity errors between the first data block and the remaining checksums in the first set of checksums, creating a restored first checksum to replace the first checksum corresponding to the first data integrity error.

35. (Cancelled)

36. (Previously presented) The computer-readable medium of Claim 31, wherein:

said plurality of data blocks comprises a plurality of data stripe units and a parity stripe unit; and

said determining whether the horizontal redundant relationship between the plurality of data blocks indicates an error comprises calculating a new parity stripe unit based on the plurality of data stripe units and comparing the calculated new parity stripe unit to the parity stripe unit from the plurality of data blocks.

37. (Previously presented) The computer-readable medium of Claim 31, wherein:

said plurality of data blocks comprises a first mirrored data block and a corresponding second mirrored data block; and

said determining whether the horizontal redundant relationship between the plurality of data blocks indicates an error comprises comparing the first mirrored data block and the second mirrored data block.

38. (Previously presented) The computer-readable medium of Claim 31, wherein the contents of the computer-readable medium cause the computer system to operate the storage system by performing the further steps of:

in response to detecting a first data integrity error in exactly one of the vertical redundant relationships and detecting no data integrity errors in the horizontal redundant relationship, creating a restored checksum using the data block corresponding to the first data integrity error to replace the existing checksum corresponding to the first data integrity error.

39. (Previously presented) The computer-readable medium of Claim 31, wherein the contents of the computer-readable medium cause the computer system to operate the storage system by performing the further steps of:

in response to detecting a first data integrity error in exactly one of the vertical redundant relationships and detecting a second data integrity error in the horizontal

redundant relationship, creating a restored data block using the horizontal redundant relationship to replace the data block corresponding to the first data integrity error and comparing the restored data block to the checksum corresponding to the first data integrity error.

40. (Original) The computer-readable medium of Claim 39, wherein the contents of the computer-readable medium cause the computer system to operate the storage system by performing the further steps of:

in response to a mismatch between the restored data block and the checksum corresponding to the first data integrity error, creating a restored checksum using the restored data block to replace the checksum corresponding to the first data integrity error.

41. (Previously presented) The computer-readable medium of Claim 31, wherein the contents of the computer-readable medium cause the computer system to operate the storage system by performing the further steps of:

in response to detecting a first data integrity error in a first vertical redundant relationship, detecting a second data integrity error in a second vertical redundant relationship, and detecting no data integrity errors in the horizontal redundant relationship, reporting a data loss condition.

42. (Previously presented) The computer-readable medium of Claim 31, wherein the contents of the computer-readable medium cause the computer system to operate the storage system by performing the further steps of:

in response to detecting a first data integrity error in a first vertical redundant relationship, detecting a second data integrity error in a second vertical redundant relationship, and detecting a third data integrity error in the horizontal redundant relationship:

creating a first restored data block using the horizontal redundant relationship to replace the data block corresponding to the first vertical redundant relationship; comparing the first restored data block to the checksum corresponding to the first vertical redundant relationship; creating a second restored data block using the horizontal redundant relationship to replace the data block corresponding to the second vertical redundant relationship; and comparing the second restored data block to the checksum corresponding to the second vertical redundant relationship.

43. (Original) The computer-readable medium of Claim 42, wherein the contents of the computer-readable medium cause the computer system to operate the storage system by performing the further steps of:

reporting a data loss condition in response to either:

- (a) a mismatch between the first restored data block and the checksum corresponding to the first vertical redundant relationship and a mismatch between the second restored data block and the checksum corresponding to the second vertical redundant relationship; or
- (b) a match between the first restored data block and the checksum corresponding to the first vertical redundant relationship and a match between the second restored data block and the checksum corresponding to the second vertical redundant relationship.

44. (Original) The computer-readable medium of Claim 42, wherein the contents of the computer-readable medium cause the computer system to operate the storage system by performing the further steps of:

in response to a match between the first restored data block and the checksum corresponding to the first vertical redundant relationship and a mismatch between the second restored data block and the checksum corresponding to the second vertical redundant relationship, creating a restored checksum using the second

restored data block to replace the checksum corresponding to the second vertical redundant relationship.

45. (Original) The computer-readable medium of Claim 31, wherein the contents of the computer-readable medium cause the computer system to operate the storage system by performing the further steps of:

in response to detecting data integrity errors in at least three of the vertical redundant relationships, reporting a data loss.

46. (Previously presented) A storage system, comprising:

a plurality of storage devices configured to store a plurality of data blocks and a plurality of checksums, wherein each data block in said plurality of data blocks has a first type of redundant relationship with a corresponding one of the plurality of checksums and each data block in said plurality of data blocks has a second type of redundant relationship with the remaining data blocks in said plurality of data blocks; and

an array manager coupled to said plurality of storage devices, wherein said array manager is configured such that in response to an indication of a data integrity error in at least one of the plurality of data blocks, said array manager determines whether the first type of redundant relationships between each of the remaining data blocks and the corresponding checksums indicates an error;

wherein the array manager further determines whether the second type of redundant relationship between the plurality of data blocks indicates an error.

47. (Previously presented) The storage system of Claim 46, wherein:

said array manager is configured to determine whether the first type of redundant relationships between each of the remaining data blocks and the corresponding checksums indicates an error by calculating a new checksum for each of the remaining data blocks in the plurality of data blocks and comparing the

calculated new checksum to the checksum from the plurality of checksums corresponding to that data block.

48. (Original) The storage system of Claim 46, wherein:

each data block in the plurality of data blocks has a vertical redundant relationship with a set of corresponding checksums, and each of the checksums in the set of corresponding checksums has a horizontal checksum redundant relationship with the other checksums in the set of corresponding checksums.

49. (Original) The storage system of Claim 48, wherein:

said array manager is configured such that in response to detecting a first data integrity error between a first data block and a first checksum from a first set of checksums corresponding to the first data block, said array manager reviews the redundant relationships between the first data block and the remaining checksums in the first set of checksums; and

said array manager is further configured such that in response to detecting no data integrity errors between the first data block and the remaining checksums in the first set of checksums, said array manager creates a restored first checksum to replace the first checksum corresponding to the first data integrity error.

50. (Cancelled)

51. (Previously presented) The storage system of Claim 46, wherein:

said plurality of data blocks comprises a plurality of data stripe units and a parity stripe unit; and

said array manager is configured to determine whether the second type of redundant relationship between the plurality of data blocks indicates an error by calculating a new parity stripe unit based on the plurality of data stripe units and comparing the calculated new parity stripe unit to the parity stripe unit from the plurality of data blocks.

52. (Previously presented) The storage system of Claim 46, wherein:

said plurality of data blocks comprises a first mirrored data block and a corresponding second mirrored data block; and

said array manager is configured to determine whether the second type of redundant relationship between the plurality of data blocks indicates an error by comparing the first mirrored data block and the second mirrored data block.

53. (Previously presented) The storage system of Claim 46, wherein:

said array manager is configured such that in response to detecting a first data integrity error in exactly one of the first type of redundant relationships and detecting no data integrity errors in the second type of redundant relationship, said array manager creates a restored checksum using the data block corresponding to the first data integrity error to replace the existing checksum corresponding to the first data integrity error.

54. (Previously presented) The storage system of Claim 46, wherein:

said array manager is configured such that in response to detecting a first data integrity error in exactly one of the first type of redundant relationships and detecting a second data integrity error in the second type of redundant relationship, said array manager creates a restored data block using the second type of redundant relationship to replace the data block corresponding to the first data integrity error and compares the restored data block to the checksum corresponding to the first data integrity error.

55. (Original) The storage system of Claim 54, wherein:

said array manager is configured such that in response to a mismatch between the restored data block and the checksum corresponding to the first data integrity

error, said array manager creates a restored checksum using the restored data block to replace the checksum corresponding to the first data integrity error.

56. (Previously presented) The storage system of Claim 46, further comprising:

said array manager is configured such that in response to detecting a first data integrity error in a first one of the first type of redundant relationship, detecting a second data integrity error in a second one of the first type of redundant relationship, and detecting no data integrity errors in the second type of redundant relationship, said array manager reports a data loss condition.

57. (Previously presented) The storage system of Claim 46, wherein:

said array manager is configured such that in response to detecting a first data integrity error in a first one of the first type of redundant relationship, detecting a second data integrity error in a second one of the first type of redundant relationship, and detecting a third data integrity error in the second type of redundant relationship, said array manager:

creates a first restored data block using the second type of redundant relationship to replace the data block corresponding to the first one of the first type of redundant relationship;

compares the first restored data block to the checksum corresponding to the first one of the first type of redundant relationship;

creates a second restored data block using the second type of redundant relationship to replace the data block corresponding to the second one of the first type of redundant relationship; and

compares the second restored data block to the checksum corresponding to the second one of the first type of redundant relationship.

58. (Original) The storage system of Claim 57, wherein:

said array manager is configured such that said array manager reports a data loss condition in response to either:

- (a) a mismatch between the first restored data block and the checksum corresponding to the first one of the first type of redundant relationship and a mismatch between the second restored data block and the checksum corresponding to the second one of the first type of redundant relationship;
- (b) a match between the first restored data block and the checksum corresponding to the first one of the first type of redundant relationship and a match between the second restored data block and the checksum corresponding to the second one of the first type of redundant relationship.

59. (Original) The storage system of Claim 57, wherein:

said array manager is configured such that in response to a match between the first restored data block and the checksum corresponding to the first one of the first type of redundant relationship and a mismatch between the second restored data block and the checksum corresponding to the second one of the first type of redundant relationship, said array manager creates a restored checksum using the second restored data block to replace the checksum corresponding to the second one of the first type of redundant relationship.

60. (Original) The storage system of Claim 46, wherein:

said array manager is configured to report a data loss condition in response to detecting data integrity errors in at least three of the first type of redundant relationships.